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**NOTES UPON SOME GEOMETRIC EARTHWORKS, WITH  
CONTOUR MAPS.**

BY W. H. HOLMES.

The ancient works to which this paper refers have been described and in a measure illustrated in numerous publications, notably in the great work of Squier and Davis and in the reports of Dr. Cyrus Thomas. The reason for again bringing them to the attention of archeologists is found in the fact that a recent survey has been made in which new methods were employed and results of considerable interest are assumed to have been secured. It is important that the maps made should be published along with an adequate record of the work done. This resurvey was made as the result of a discussion initiated by Dr. Thomas in which certain features of configuration and mensuration were considered. The letter of Dr. Thomas may very properly be given in this place :

*To the Director, Bureau of Ethnology.*

SIR: I have reached the point in the final work of preparing my second volume for publication where I am compelled to express some opinion in regard to two or three of the geometrical works of Ohio. I have just returned from a visit to them, made for the purpose of studying the topography. Now, what I wish especially at present is to ask you to submit the following questions to some person who will endeavor to give me the best possible answers which the data will admit.

Suppose that previous to the year 1760 a surveyor, officer, or other person had been required to lay out a large circular work on level ground in Ohio, what degree of symmetry could be expected? What instruments and what unit of measure would have been used?

The question is not purely theoretic, but relates to two works found in Ohio and described in my bulletin on "The Circular, Square and Octagonal Earthworks of Ohio"—one known as "Observatory Circle," described on pp. 16-17, pl. 3; the other the circle of "The High Bank Works," described on pp. 21-22, pl. 6. The object in view is to ascertain, first, whether the dimensions of these works coincide with the unit of measure used at that time; second, whether the degree of accuracy likely to have been attained was greater than that which might have been attained by Indians by the use of rope or cord in striking a circle.

That we must go some time back of the year 1760 we know historically, as these works were visited that year and found to be covered in some places by trees.

I do not expect any other result from this inquiry than to cast strong doubt upon the theory of European or civilized assistance in the construction of these works, but I wish to obtain the opinion of some one devoting attention to the mathematical sciences.

It is remarkably strange, however, that a circumference of 50 chains (4-pole) will give so nearly the exact diameter of these two works.

Very respectfully,

CYRUS THOMAS.

This letter was referred to Messrs. Henry Gannett and Marcus Baker, the former Chief Geographer and the latter Chief Computer of the United States Geological Survey. The subject was considered by these gentlemen, and the Director authorized the resurvey of the Observatory circle at Newark, the Fair Ground circle at Newark, and a similar circle at Chillicothe. My attention having been called to the proposed survey, I prepared the following letter, which was intended to call attention to certain features of the survey of such remains that in my opinion deserved more careful attention than would probably be given them by the topographic engineer. This letter may be included in this report, and is as follows:

*To the Director, United States Geological Survey.*

SIR: I learn from Mr. Marcus Baker that it is proposed that he and Mr. Gannett visit a number of the so-called geometric earthworks in Ohio for the purpose of surveying and otherwise studying them, with a view of acquiring an exact knowledge of their configuration, etc. Being much interested in this matter, I take the liberty of calling your attention to a few points that may otherwise be overlooked, thus leaving the work in unsatisfactory shape.

In the first place, I would observe that so far as the determination of the present shape of a given monument or work is concerned, it is to be expected that skilled topographic engineers will be able to reach accurate results and to express these fully and clearly. It should be noted, however, that these ancient works are often obscure, and that the forms are in all cases rounded and indefinite. Before the application of the machinery of precision to the measurement of such forms the eye must be employed to assist in forming judgments as to the position of datum points, and this necessarily introduces a considerable element of uncertainty. In selecting the summit point of a mound or the median or crest line of a work, the judgments of two persons may vary a number of feet, and where indefinite marginal outlines are considered there is much greater chance of difference. The fixing of datum points for the measurement of a work of this class calls for mature consideration by a number of

observers of experience and skill. In this way fairly reliable results may be obtained, but it must be observed, in the second place, that these results relate to the present shape of the work only, whereas the real aim of the investigation is to secure an accurate knowledge of the original configuration. Conclusions based upon measurements that do not take into consideration all possibilities of form modification from the period of original construction to the present day must be unsatisfactory and may be seriously misleading. How, then, shall this matter of the modification of an ancient work be considered and by whom? Who shall say what change has taken place through prolonged use by the builders themselves or how much the encroachments of succeeding peoples have reduced or increased the original symmetry? Who is to determine the effect of rain and wind and to estimate the kind and amount of degradation by gravity in its various forms? Who can give an intelligent notion of the action of these and numerous other agents of deformation and of the results attributable to them? It is manifest that two classes of experts should consider the works conjointly, those having an intimate acquaintance with the action of the modifying agents and those well versed in the nature and history of the works examined.

In brief, what I wish to say is (1) that the mean of a number of judgments as to datum points for measurement is better than a single judgment; (2) that each datum point is useful in proportion to its approximation to the original point it is intended to represent, and (3) that the degree of that approximation will depend upon the competency of the experts employed. I beg respectfully to suggest that if this work is taken up the party of survey comprise, beside the engineers, at least one geologist having a ripe knowledge of the subtle but powerful monument-deforming agencies of nature, and one or more ethnologists equally well informed upon the nature and history of the structures to be measured.

Very respectfully yours,

WM. H. HOLMES.

The party consisted of Messrs. Gannett, Baker, Aplin, and the writer, and took the field in October, 1891. It was found impossible to secure the aid of all the specialists recommended in my letter; but this proved not a serious matter, as Mr. Gannett desired not so much to attempt the answer of Dr. Thomas' questions as to try the experiment of employing contours in the mapping of the earthworks and at the same time to test the accuracy of the former surveys.

The work in the field was confined mainly to the preparation of contour maps of the three circles mentioned. It is not claimed that new elements of great importance have been added or that the work is greatly superior to that of previous surveys. The chief advantage of the present survey consists in the employment of the

contour system, by which means we are able to exhibit absolute relief, and to a certain extent the relations of that relief to the topography of the sites. By this method there is some loss of graphic clearness because of the inadequacy of expression of contours of relatively wide interval, but the expression of hachure maps on the scale heretofore used is notably inadequate in this and in many other directions. The defects of the earlier maps are more pronounced for the reason that the final drawings were made from field sketches subject to interpretation by the draughtsman. In the present case the drawing was done upon the spot. The three maps have been engraved and are presented herewith.

The visit was made in the fall of the year, when the conditions happened to be the best possible; crops had been harvested and the foliage had to a great extent fallen from the trees, the only impediment encountered being the scattered forest trees covering portions of the Newark works. The plane-table was used in the survey, and the hand level served to determine the profiles. For convenience of mapping it was deemed best to place stakes upon the crests of the works at intervals of about 100 feet. That these might represent the true or original crest as well as possible under the circumstances, Mr. Gannett and the writer did the work conjointly. The crests are as a rule quite flat and the median line is difficult to determine. On those portions of the walls reduced by the plow or modified by trails and roads the limit of possible error may in cases reach as much as six feet, but elsewhere this range is probably never more than two or three feet. That the errors actually made average very low is shown by the close correspondence between the results in this and in the former survey. Profiles were made at each stake with the hand level, extending from the outer to the inner margin of the structure, no matter how much spread out by the plow or by other agencies of degradation. Contours were drawn in upon the spot and the map thus made was ready for the engraver.

In transmitting these results to the Director, Mr. Gannett presented the following memorandum:

“The methods and instruments employed in surveying these three works were identical and can be described in a few words. The principal instrument used was the plane-table, and locations were made by triangulation. Within each circle a base-line was measured with a steel tape. Points upon the summit of the circle at an

average distance apart of about a hundred feet were selected and marked by stakes. Each of these stakes was then cut in upon the plane-table from each end of the base-line, and checks on the locations were obtained by occupying in a similar manner points thus located upon the summit of the circle.

“At the same time that these points were located their heights were measured with the vertical arc of the alidade, a telescopic alidade being, of course, employed. There was thus established around the summit of the circle the location and height of a series of points approximately one hundred feet apart. Then at each of these points a cross-section was made of the ridge, including, in the case of the Fair Ground circle, the ditch also. These cross-sections were made by the use of the steel tape for distances, and a hand level for differences of height. Special care was devoted to the entrance to the Fair Ground circle and the observatory of the Observatory circle, upon which many measurements were made in order to get their shape and dimensions correctly. Based upon these measurements, the works were sketched upon the plane-table sheet while upon the ground.

“The survey of the Observatory circle, which was the first survey, occupied four men for the greater part of two days, that of the Fair Ground a little more than a day, while the High Bank circle, which was the last surveyed, required the work of three men somewhat less than a day.”

Although no attempt has been made to answer fully the questions asked by Dr. Thomas, it would appear that, on account of the decided variations from symmetry in the figures themselves and the impossibility of saying whether these variations have been increased or diminished by erosion, the discussion of the possible use of any known unit of measure is practically useless.

If the works had been laid out by the whites there appears to be no reason why the builders should have adhered rigidly to the true geometric form based upon the unit of measure employed, and certainly there is not the least doubt that if the aborigines desired a true circle they had the capacity to lay it out and to construct the work accordingly.

#### THE OBSERVATORY CIRCLE.

The circular embankment known as the Observatory circle has attracted a large share of attention, and is only inferior in interest

and importance to its rival in the same great group or system of works, the Fair Ground enclosure. The survey of Squier and Davis was made nearly fifty years ago, and before the primitive forest had been disturbed or the embankment seriously modified. Investigators can safely rely upon their statements and illustrations as to the appearance and condition of the work at that time, and the present examinations show that their map and illustrations, though wrong in some minor details, are in the main correct. In their map of the group of works this circle is represented as symmetric and uniformly well preserved. A slight discrepancy is seen between the representation of the Observatory mound on their map and that shown in their cut. The latter, according to present observations, is correct as to the relation of the parts. The error in their general map crept in, no doubt, during the processes of drawing and engraving. The cut given by Squier and Davis is reproduced in Fig. 1. The form

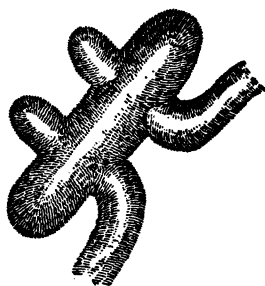


FIG. 1.—From Squier and Davis.

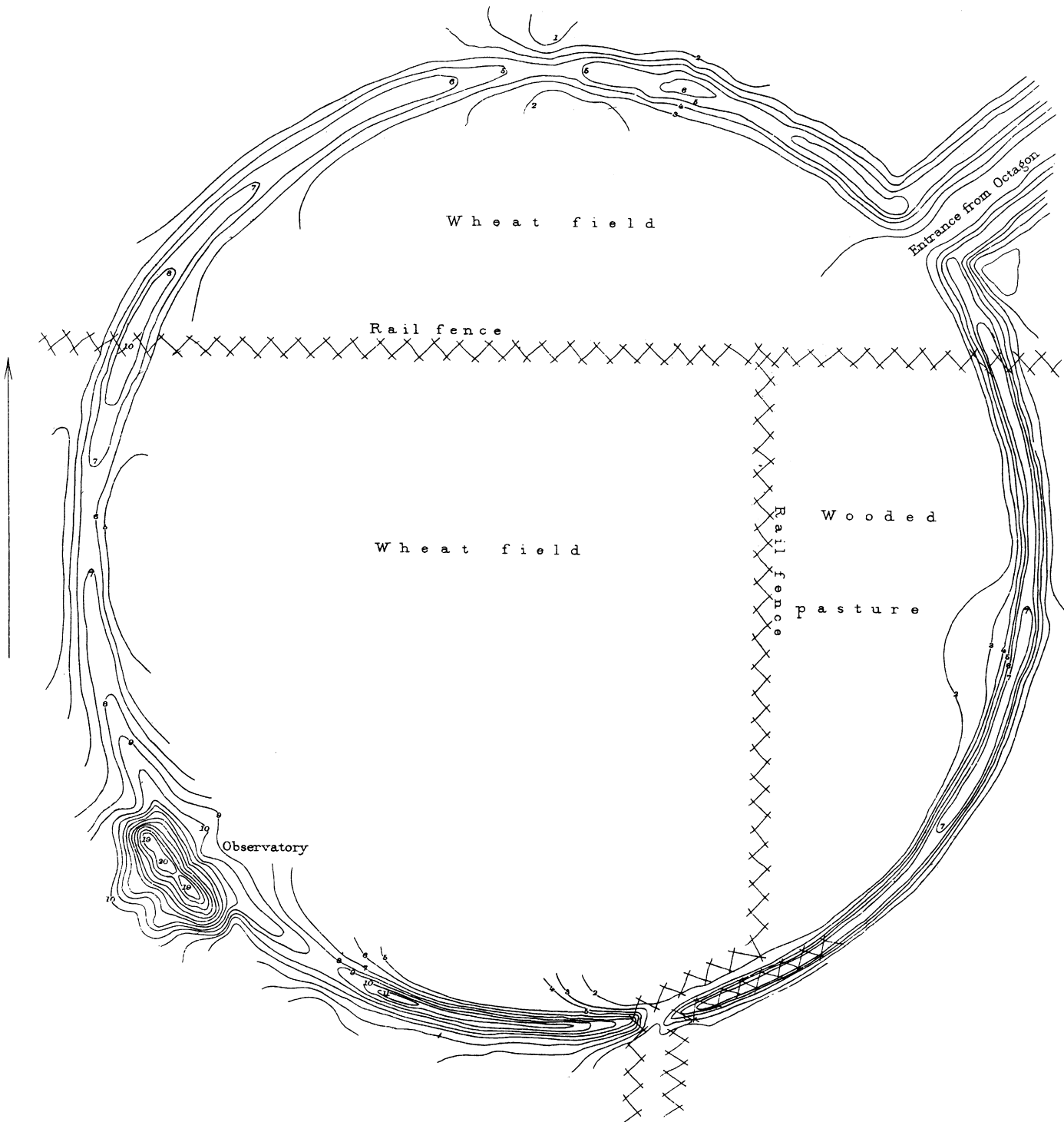


FIG. 2.—Present conformation.

The "observatory" feature of the circle.

as it appears to-day is given on nearly the same scale in the accompanying map, Pl. I. Comparison can be instituted to better advantage, however, with the hachured sketch given in Fig. 2, which is on a larger scale. The form is seen to be more rounded and indefinite than in the Squier and Davis cut, although it is slightly emphasized throughout. A careful study of the earthwork itself is necessary to the discovery of the precise relations of the cross-ridge to the out-curved ends of the inclosing wall. In the map published by Dr. Thomas<sup>1</sup> these relations are not brought out, and a slightly

<sup>1</sup> Cyrus Thomas. Circular, Square and Octagonal Earthworks. Bulletin, Bureau of Ethnology, 1889.



OBSERVATORY CIRCLE. NEAR NEWARK. O.

Scale 150 feet to 1 inch, or 1:1800

Contour Interval 1 foot

Surveyed in 1891

erroneous impression is given of the manner in which the out-curved walls of the circle connect with the cross-ridge or link.

The slight depression now seen in the middle part of the connecting wall may be the result of recent excavations, which have left numerous pits and have tended to destroy the symmetry of the work. It may be further stated that the map furnished by Dr. Thomas does not express literally the present condition of the encircling wall, but represents it as of uniform width and height throughout. The contour map will serve much better as a record of the present condition of the work, expressing, though still imperfectly, the reductions made by the plow and for roadways. As shown in the contour map, the wall northward of the observatory mound and continuing around to the gateway on the northeast, save at the first fence crossing, is much reduced in height and greatly spread out by the plow and harrow. From a point a little to the southeast of the gateway around the eastern side to the observatory hill, the original forest has never been fully removed, save at two points—one at the lane crossing, where the wall is reduced almost to the original level of the ground, and the other next the observatory, where for a space of about 100 feet it is reduced to less than half the original height by the plow. Between these two reduced spaces the embankment preserves apparently nearly its original height, but the plow has encroached upon the inner and outer margins, reducing the width and altering the profile.

So far as now can be determined, the embankment has never had other than a well-rounded profile, the crest being as acute as stability would allow and the sides descending at a high angle to the ground level.

The original conformation and use of the peculiar feature known as the observatory must remain forever a secret. The slight depressions inside and outside of the middle of the connecting segment are suggestive of a former passage through or beneath that portion of the work. A depression some five or six feet deep and perhaps 200 feet in diameter occurs just outside of the wall at this point, another may be seen in the angle between the wall of the circle and the south wall of the gateway leading into the octagon, and a third occurs on the outside just to the east of the lane at the crossing of the circle. These may be remnants of the pits from which the earth for construction was obtained. There are other slight irregularities in the surface within and without the inclosure, but it cannot be shown that they are in any case artificial.

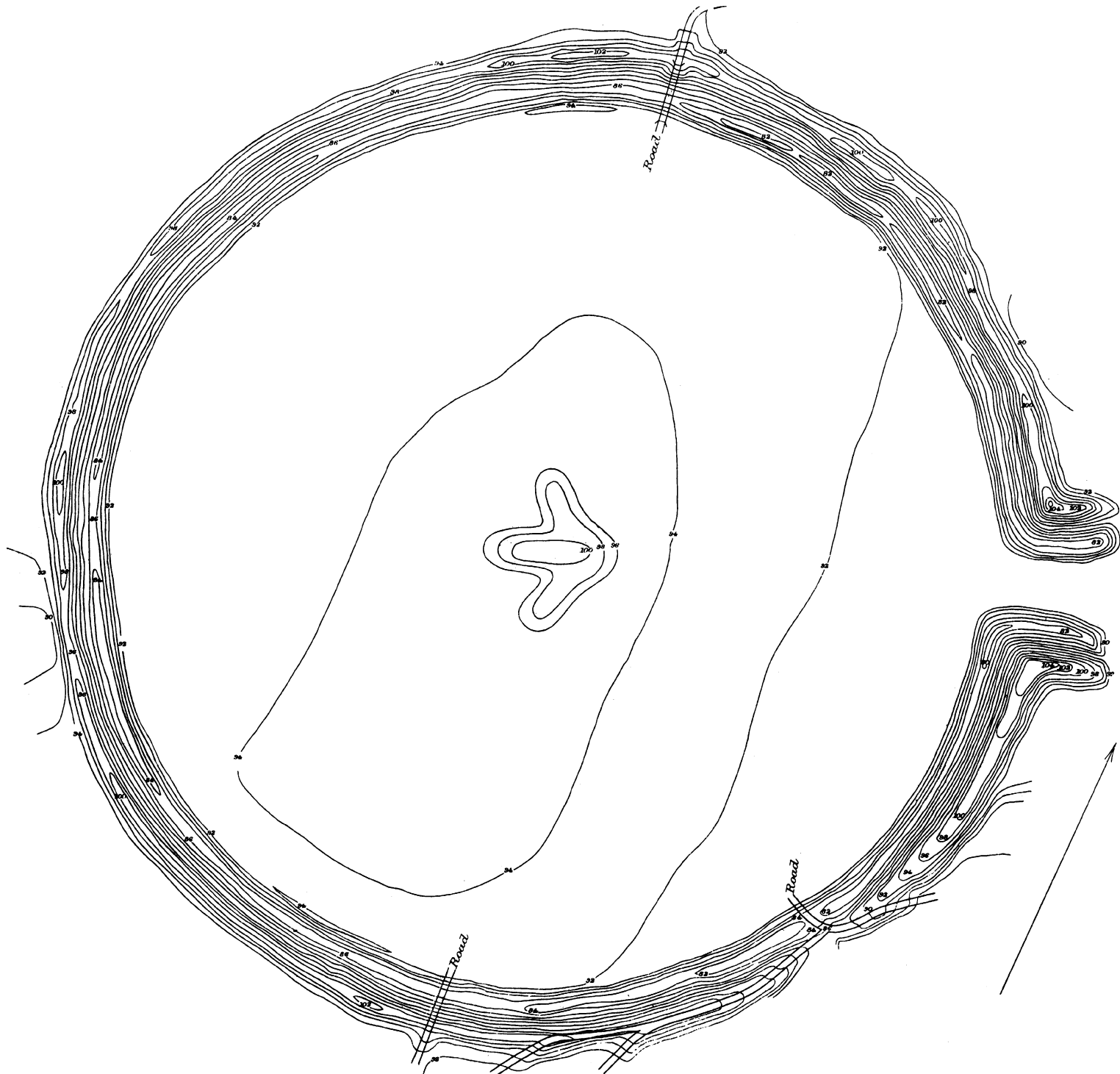
On the west side and not more than 200 feet from the wall of the circle, the plain upon which the works are situated falls off in a steep terrace some 25 feet high to a lower level but slightly higher than the flood plain of Raccoon creek.

Twenty-nine stakes were set. The most satisfactory circle obtainable had a diameter of 1,054 feet; only one stake of the 29 varied more than  $3\frac{1}{2}$  feet from this circle, and that stake was at the southeast opening of the gateway, where degradation has been confined entirely to one side of the wall. These figures were obtained before the measurements of Dr. Thomas were referred to, and the comparison is interesting as showing the very close approximation of the two surveys.

#### THE FAIR GROUND CIRCLE.

The Observatory circle is fast disappearing from view. The Fair Ground circle, in the same group, a mile farther east, has remained in nearly its primitive state. This is no doubt due greatly to the massiveness of the work, to its steep, high declivities forbidding intrusion, and to the presence of an inclosed ditch difficult to cross even afoot. It is still, as described by Squier and Davis fifty years ago, a most impressive work, its grand dimensions causing one to wonder if the North American Indian was ever equal to the task of its construction.

In beginning the work of survey a base-line was laid down across the level grounds of the inclosure, and stakes at intervals of about 100 feet were set as nearly as possible upon the crest line as determined by the adjacent slopes. Profiles were made through each of these stakes at right angles to the trend of the wall. As stated by Squier and Davis, by Dr. Thomas and others, the inclosure varies considerably from a true circle, the greatest variation of diameters being about 33 feet. There are numerous irregularities of the crest line as now determinable. The effect is as if the builders had worked by a large number of straight lines rather than by a regularly curved one. The floor within the inner brink of the trench is quite uniform in appearance, although it varies in level some four or five feet. Without the wall the surface of the ground is considerably varied, a very decided depression occurring southward from the gateway and adjacent to the marked sag in the wall. It is not improbable that this depression and that north of the work, and



FAIRGROUND CIRCLE. NEAR NEWARK. O

Scale, 150 feet to 1 inch, or 1:1800

Contour Interval 2 feet

Surveyed in 1891

containing water at the time of the Squier and Davis survey, were the source of a large part of the earth and gravel used in construction. These basins served also, no doubt, to furnish a supply of water to the occupants of the mound-building community. There are no vestiges of canals leading from the river to these reservoirs and no indication of a means by which water could have been conducted into the great trench within the inclosing wall. As shown by the contour map, the embankment is, and no doubt always was, higher and more massive at and near the gateway. It is difficult to say just how much of the variation from symmetry now so noticeable is due to original construction and how much to subsequent degradation. The deep depression in the profile at the south side was doubtless a feature of the original conformation. The material composing the work is for the most part a rather fine gravel which sustains forms in which it is embodied with great permanence. The plow of the white man has not invaded this great work, but roads and footpaths have produced many changes, and if the present use of the site as a fair ground is not discontinued, a few generations will witness its practical demolition. The crest and many of the more accessible slopes are already modified by roads and footpaths. The construction of a race-track has also served to destroy the inner margin of the trench around the western border.

The trilobate mound in the center of the inclosure is so low that it is not well expressed by the contours. The height of the central mass is nearly five feet above the general level; the lateral lobes are about three feet high. At present there are no traces of the four prominences or crests indicated upon the map of Squier and Davis, Fig. 12, p. 68, or of the two prominences on the lateral lobes shown by Dr. Thomas; neither is there any indication of a low, curved embankment just beyond the central lobe, as indicated by the former authors. It should be noted that the contour map does not assume to give all details of conformation and may be inaccurate in a small way in the expression of what is given. The only measurements made of height and width were sections at the stakes, and the contouring between these profiles was done by the eye. The contour interval is two feet. It may be said of the map given by Dr. Thomas that as to general shape and dimensions it is sufficiently accurate, but errors in detail have crept in, perhaps through misinterpretation by the draughtsman. A comparison with the contour map, Pl. II, will show that the width of the embankment and trench is not great

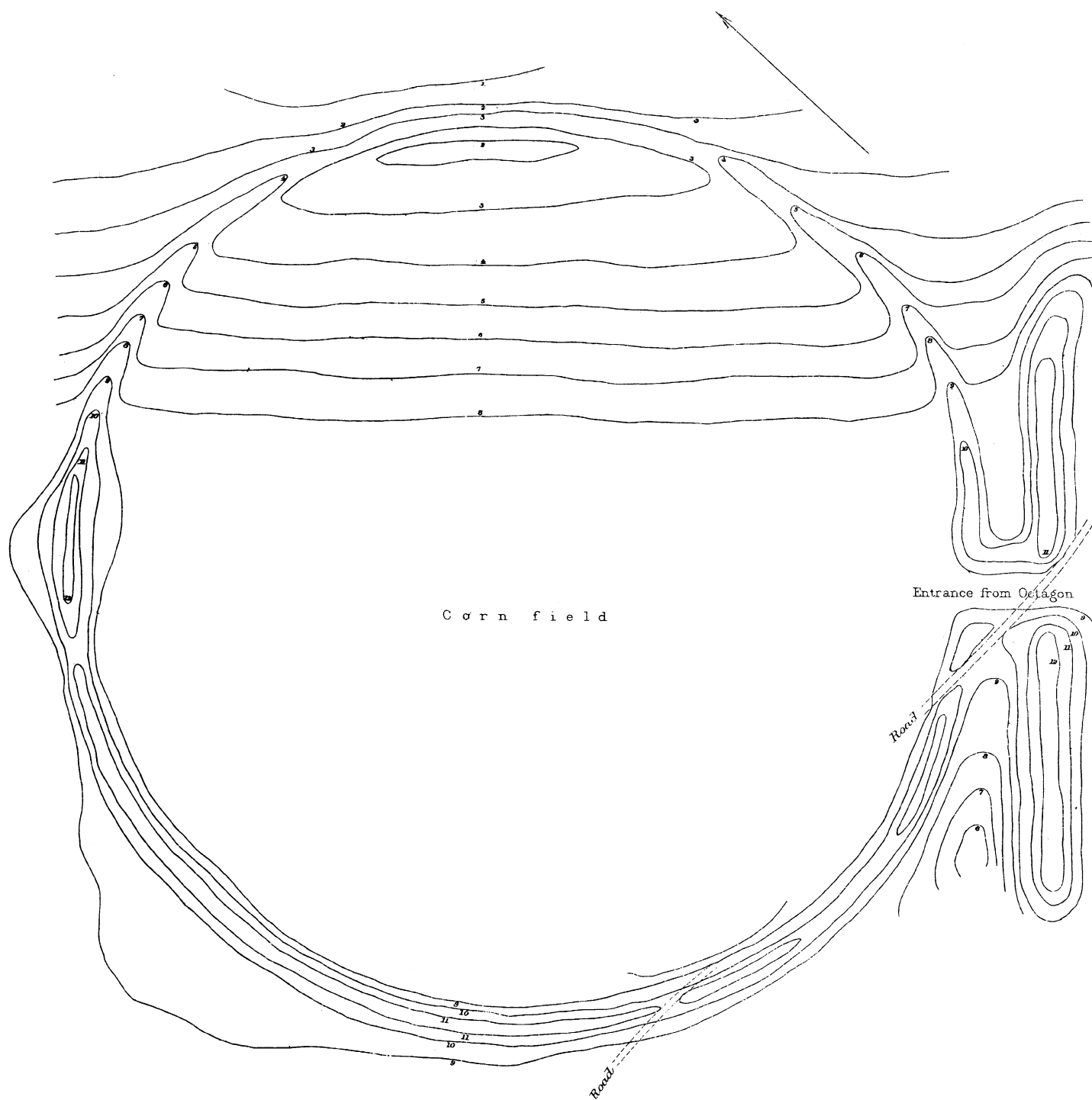
enough and the width of the roadway at the entrance is too great as a result of this lack of width in the walls and trench. There is in Dr. Thomas' map no attempt at the expression of variations of height or width or of details of conformation.

The following are a few of the measurements made: 26 stakes were set upon the crest of the wall. Upon the plane-table sheet a center was found experimentally by projecting a circle, leaving nearly an equal number of stakes within and without, the mean distance from the line of those without equalling the mean distance of those within. The diameter of this circle was 1,185 feet. The outermost stake was 12 feet outside of this circle and the innermost stake 13 feet inside, making a total variation of 25 feet. There was, therefore, a possible difference of 50 feet in diameters between stakes. By measurement, however, it was found that the largest diameter obtainable was 1,200 feet and the shortest 1,167 feet; an actual variation of 33 feet. The center used is 8 feet north of the median line of the trilobate mound. The figures placed upon the contour lines on the map, Pl. II, begin with 80 feet, as the lowest level in the trench, and extend to 104 feet, the highest point of the wall.

#### THE HIGH BANK CIRCLE.

The High Bank circle, near Chillicothe, Ohio, was originally one of the finest specimens of its class extant. The embankment was inferior, apparently, in mass to that of the Observatory circle at Newark, but no part of it has escaped the plow, and the original height and profile cannot be ascertained.

The survey made by Mr. Gannett was intended only to determine the dimensions and approximation to a circle. It was not considered necessary to attempt to represent the relief, which is so slight and withal so uniform. The writer took the liberty, however, of sketching in contour lines of about one foot interval, the work being based upon profiles obtained by the hand level. The greatest height measured was 49 inches, and the mean of 32 observations of height made at nearly equal intervals about the circle is 30 inches. As roughly indicated upon the map, this circle does not occupy level ground, there being a descent of about seven feet from the main level toward the northeast. This descent is part of the face of a low terrace which extends from the river southeastwardly across the prairie.



# HIGH BANK CIRCLE. NEAR CHILLICOTHE, O.

Scale, 150 feet to 1 inch, or 1:1800

Contour Interval 1 foot

Surveyed in 1891

The embankment is cut through in two places for a roadway, as indicated upon the map, and at one point, about 400 feet to the north of the gateway, there is a break or passageway of ancient date. By Squier and Davis and by Dr. Thomas this break is indicated as being absolute and abrupt, but this is not the case. The descent to the depression is so gentle as to be barely perceptible and the reduction is complete only on the inside. On the other side there is a rise of nearly a foot to the lowest part of the depression.

In making a series of sections across the embankment it was found that the mass was nearly twice as wide as indicated by Dr. Thomas' figures. It is evident that his measurements were in the nature of a compromise between what is and what was thought to have been. The ground having been freshly plowed and harrowed, we found it possible to determine somewhat closely the points at which the natural surface or profile changed to the artificial.

The following diameters, somewhat equally distributed about the crest line, may be given: 1,057, 1,062, 1,052, 1,055, 1,060, 1,060, 1,050, 1,045. The greatest variations of the 30 stakes set from a circle 1,057 feet in diameter is one 20 feet inside and another 10 feet outside, the former marking the decided eccentricity in the crest line 250 feet north of the gateway and the latter occurring at the north, where the wall is much flattened out and obscured. Of twenty stakes set on the best preserved part of the crest no one varied more than three feet from the circle drawn. The sum of the variations inside equalled the sum of those outside.

If the chain was used in laying out and regulating the construction of these three works the variations from exactness (66 feet) as indicated by our determinations would be as follows: 65.9 for the Observatory circle, a variation of  $\frac{1}{8}\frac{1}{8}\frac{1}{8}$ ; 66.8 for the Fair Ground circle, a variation of  $\frac{1}{8}\frac{1}{8}\frac{1}{8}$ , and 65.06 for the High Bank circle, a variation of  $\frac{1}{10}\frac{1}{8}\frac{1}{8}$ . These may well be regarded as extremely close approximations if the chain was used and remarkable coincidences if accidental.

Gunter's chain was first used about the year 1600 and would hardly have been employed in the Ohio valley until many years later. It should be noted that the circle determined in each case is the mean of a number of circles covering the full range of variation of the earthwork from that circle, and should not be thought of as necessarily representing any original circle laid out by the builders, since that circle may as readily have been upon the inner or outer margin as upon the center line of the proposed work.